Visual perception of writing and pointing movements

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Received 15 May 2002, in revised form 24 November 2004; published online 12 August 2005

Abstract. Studies of movement production have shown that the relationship between the amplitude of a movement and its duration varies according to the type of gesture. In the case of pointing movements the duration increases as a function of distance and width of the target (Fitts’ law), whereas for writing movements the duration tends to remain constant across changes in trajectory length (isochrony principle). We compared the visual perception of these two categories of movement. The participants judged the speed of a light spot that portrayed the motion of the end-point of a hand-held pen (pointing or writing). For the two types of gesture we used 8 stimulus sizes (from 2.5 cm to 20 cm) and 32 durations (from 0.2 s to 1.75 s). Viewing each combination of size and duration, participants had to indicate whether the movement speed seemed “fast”, “slow”, or “correct”. Results showed that the participants’ perceptual preferences were in agreement with the rules of movement production. The stimulus size was more influential in the pointing condition than in the writing condition. We consider that this finding reflects the influence of common representational resources for perceptual judgment and movement production.

DOI:10.1068/p3388

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1 Introduction

Several studies have shown that sketchy depictions of human movements (eg point-light displays) are sufficient to allow discrimination between human and physical motion (Bingham et al 1995), recognition of actions such as walking or dancing (Johansson 1973), identification of the gender of an actor (Kozlowski and Cutting 1977) or of the physical properties of handled objects (Runeson and Frykholm 1981). Furthermore, it appeared that participants were better at recognising self-generated actions than actions generated by others (Beardworth and Bukner 1981; Knoblich and Prinz 2001).

As a potential explanation of the high sensitivity of the visual system to human motion, a number of studies suggested that some form of knowledge, related to the motor dimension of human behaviour, could contribute to perception. In a classical experiment, Viviani and Stucchi (1992) asked participants to select the stimulus the velocity of which appeared as the ‘most uniform’. The stimulus was a moving light spot describing elliptic or pseudorandom trajectories. The principal independent variable was the distribution of instantaneous velocity along the trajectory. In one case, velocity and curvature were inversely related by a two-thirds power law (Viviani and McCollum 1983). For the other, ‘non-biological’ situations, the value of the exponent of the power relation was increased or decreased in steps of one third (including the zero situation corresponding to a stimulus with a true uniform velocity). The results showed that, whatever the trajectory, the participants considered the biological stimulus as having the most uniform velocity distribution. The other stimuli, including the truly uniform stimulus, were judged atypical and jerky. Viviani and Stucchi explained this perceptual preference for biological motion by postulating that the visual perception of dynamic events involved implicit motor competences.
Comparable results were observed in an even subtler perceptual task. Studies focused on the production of sequential movements (e.g., typing or handwriting) revealed a motor anticipation phenomenon (Thomassen and Schomaker 1986; Viviani and Laissard 1996). This anticipation resulted in the adjustments of kinematics during the first component of motor sequences. For example, in cursive handwriting, the velocity profile of a first letter (l) changed as a function of the size (ll versus le) or the direction of rotation (ll or le versus ln) of the forthcoming letter. It was shown that when the end-point motions of a pen drawing the first letter l of these diagrams were displayed on a video-screen, participants were able to guess the identity of the following letter (Orliaguet et al 1997). Complementary analyses indicated that this perceptual anticipation phenomenon depended essentially on the kinematic cues that represented the ‘motor signature’ of anticipation (Kandel et al 2000). Again, these results suggested that a tacit knowledge of the motor anticipation rules was accessible to the participants.

The present study was carried out within this theoretical framework. It focused on the visual perception of two different types of gesture: writing and pointing movements. We chose these movements because the rules describing the relationships between their amplitude and their duration differ.

In fluent writing, movement duration appears to be weakly dependent on movement extent (Thomassen and Teulings 1985). This phenomenon, known as the isochrony principle, is also observed in tasks involving drawing (Viviani and Schneider 1991), grasping (Jeannerod 1984), as well as percussion movement (Delay et al 1997). It is to note that participants are not aware of the isochrony principle and rather think that movement duration increases with movement amplitude (Decety and Michel 1989).

On the other hand, several studies demonstrated that the duration of pointing movement, $T_M$, was tightly related to the distance and size of the target. Fitts (1954) described this phenomenon through the following equation: $T_M = a + b \log(2D/W)$, $a$ and $b$ being two constants, with $D$ and $W$ representing, respectively, the distance to the target and its width. This law has been refined in a variety of equations (see Plamondon and Alimi 1997 for a review) but always predicts, at constant target size, an increase in movement time as the pointing distance increases.

Our aim was to verify whether these different motor rules influenced the perceptual preferences of human participants. We displayed writing and pointing movements of varying amplitudes and durations. Participants had to judge the speed of the motion. If motion perception relies on a tacit knowledge of motor rules, the isochrony principle and Fitts’ law should differently determine the participants’ perceptual preference. Clearly, the preferred movement duration should be more influenced by the spatial extent of the trajectory in the pointing condition than in the writing condition.

2 Method
2.1 Participants
Sixty-four undergraduate students at the Pierre Mendès France University volunteered for the experiment. They were randomly assigned to one of the two experimental groups: writing ($n = 32$) or pointing ($n = 32$). An additional participant was recruited for preparing stimuli. The volunteers were rewarded with course credits.

2.2 Stimulus preparation and presentation
2.2.1 Writing movement. Movements were recorded on a graphic tablet with an electromagnetic stylus (GD.1218R, Wacom Europe GmbH, Neus, Germany; sampling rate $= 200$ Hz, accuracy $= 0.2$ mm). The additional participant produced, at self-paced rate, several $es$ in cursive handwriting. The recorded $x$ and $y$ coordinates were smoothed (Butterworth cut-off frequency $12$ Hz) and we selected one $e$ portraying fairly the shape and the kinematic characteristics of the cursive handwriting (see figure 1).
In the perception task, the writing movement was displayed on a computer screen. The motion was simulated by the sequential presentation of a black spot (diameter, \(\phi = 0.4\, \text{cm}\)) on a white background area (22 cm \(\times\) 22 cm). The recorded \(x\) and \(y\) coordinates defined the changes in the spot position between two successive presentations. The spot left no trace on the background. The letter was always centred with respect to the background area. The software, specifically designed for this experiment, allowed changing the amplitude and duration of the original movement. We selected 8 letter heights ranging from 2.5 cm to 20 cm (in steps of 2.5 cm), and 32 movement durations (ranging from 0.2 s to 1.75 s, in steps of 0.05 s). It is noteworthy that changes in height and duration strictly preserved the shape of the trajectory and the velocity profile of the original movement.

2.2.2 Pointing movement. As for the writing stimulus, the additional participant executed several pointing movements in the horizontal plane toward a circular target (\(\phi = 1\, \text{cm}\)) located 10 cm from the starting position. We selected a pointing movement (figure 1) with an almost rectilinear path and a bell-shaped tangential velocity profile. In the perception task, the pointing movement was presented on the screen with a 1 cm black square (representing the starting position) centred at the bottom of the background area and a circular target (\(\phi = 1\, \text{cm}\)) positioned above the starting position. As for the height and duration of the letters, the pointing distance ranged from 2.5 cm to 20 cm and the pointing durations ranged from 0.2 s to 1.75 s. Again, the different space and time scaling preserved the shape and the velocity profile of the original movement.

2.3 Procedure
2.3.1 Writing condition. The experiment took place in a quiet dimly lit room. The participants sat in front of the screen at a distance of about 40 cm. The instructions specified that a writing movement would be displayed on the screen (the letter \(e\) written in cursive style) and that the task consisted of judging the speed of the writing. After a 1 s display of a fixation cross, followed by a 0.5 s delay, the light spot started to move so as to write the letter with the given height and duration. Participants had to indicate, by pressing on response buttons situated below the background area, whether the speed of the movement seemed “fast”, “slow”, or “correct” (neither too fast, nor too slow). They had to answer on the basis of their first impression. Then, after a short delay, a new trial started. Each subject carried out the \(8 \times 32\) trials. The 8 stimulus sizes (letter heights) were presented as a block in random order. Within each block, the order of the 32 movement durations was also random. A 1 min delay separated each block. A complete session lasted about 30 min.
2.3.2 Pointing condition. The instruction specified that a black square, representing the starting position of a pointing movement, and a circular target, representing the target of the movement, would appear on the screen. After a short delay (1.5 s), a spot appeared and moved from the starting point to the target. As in the writing condition, the task was to judge the speed of the spot by clicking on the responses “fast”, “slow”, or “correct”. As previously, each subject carried out the 8 × 32 trials with a random order of the 8 stimulus sizes (pointing distances) and, within each block, a random order of durations. Again, a 1 min delay separated each block and a complete session lasted about 30 min.

3 Results
3.1 Relation between movement duration and stimulus size
The main analysis concerned the “correct” responses (ie the responses that directly characterised the perceptual preferences of the participants). Figure 2 shows the average (all individuals’ average) of the “correct” movement duration, $T_M$, plotted against the stimulus size.

As concerns the comparison of the writing and pointing condition, we calculated the average “correct” $T_M$ for each stimulus size and participant. Then we estimated the coefficient of correlation, slope, and intercept of the linear regression of the values of $T_M$ over stimulus size for each individual. We used the statistics: $t_{n-2} = r[(n-2)]/(1-r^2)]^{1/2}$ to test whether the correlations were greater than 0 ($\alpha = 0.05$). The results indicated that the correlation was significant for fifteen participants in the writing condition and twenty-nine in the pointing condition. A comparison of the number of significant correlations between the two groups gives $\chi^2_{1,64} = 14.25$, $p < 0.01$. The proportion of significant correlations was larger in the pointing group than in the writing group.

Next, we used a one-way ANOVA to compare the average values of the linear estimators (coefficients of correlation, slopes, and intercepts). We utilised the Fisher Z transform before averaging the correlations. As expected from the preceding result, the average correlation was lower in the writing group (mean, $M = 0.62$) than in the pointing group ($M = 0.84$): $F_{1,62} = 21.55$, $p < 0.01$. In addition, the comparison of the slopes indicated that the increase in movement duration due to stimulus size was smaller in the writing group ($M = 8$ ms) than in the pointing group ($M = 20$ ms).
Taken together, these results confirmed the lower influence of stimulus size upon movement duration in the writing condition. Finally, the comparison of the intercepts (writing, $M = 0.79$ s versus pointing, $M = 0.74$ s) was not significant ($F_{1,62} = 1.58$, ns). This latter result suggests that the baseline movement duration was similar in the two conditions. In summary, the results clearly show that the scaling of preferred movement duration with stimulus size was different in the two conditions.

3.2 Distribution of “correct” responses

Figure 3 shows the percentage of “correct” answers as a function of stimulus duration and size, for the writing and pointing groups.

The distributions of “correct” answers were asymmetric when compared to a normal (symmetric) distribution (Pearson 1895). The asymmetries, for the 8 stimulus sizes from 2.5 cm to 20 cm, ranged from 0.49 to 0.21 in the writing condition and from 0.69 to 0.02 in the pointing condition. A positive asymmetry means that the distribution of correct answers resembled a log-normal distribution. The decrease in asymmetry with increasing size could reflect a ceiling effect that seemed particularly influential in the pointing condition. In this condition, because the mean values of the movement duration perceived as “correct” increased with stimulus size, the whole distribution of correct answers was shifted towards greater stimulus duration and reached the upper limit values of the sample (see figure 3). This ceiling effect possibly led to an underestimation of the asymmetry and might have limited the increase of the mean movement duration in the pointing group.

4 Discussion

In this study we analysed the relation between preferred stimulus duration and stimulus size in the case of writing and pointing movements. The results showed that the perceptual preferences of the participants were less influenced by the spatial extents of the trajectory in the writing condition than in the pointing condition. It follows that the visual preferences for motion speed were not determined by a general law of space–time co-variation, but depended on specific rules related to motor production.
For writing movement, the perceptual preferences were compatible with the isochrony principle and for pointing movement they were roughly in agreement with Fitts’ law.

Two remarks reinforce this result. First, the ceiling effect observed in the pointing condition could have reduced the difference between the two groups. Second, we should bear in mind that, whatever the type of movement, the stimulus size referred to the stimulus height (y axis) and not to the actual trajectory length. In the writing condition, the heights of the letters ranged from 2.5 cm to 20 cm but the corresponding lengths of the letters ranged from 8.82 cm to 70.56 cm. On the other hand, in the pointing condition, trajectory lengths were almost identical to the stimulus heights. Although the trajectories were much longer in the writing condition, the durations considered as “correct” were less influenced by the stimulus size than in the pointing condition.

It is noteworthy that the isochrony principle seems to be particularly constraining for the perception of writing movement. The mean slope of the linear regressions suggests that an increase of 2.5 cm in letter size results in a mean increase of 20 ms in preferred movement duration. This is far better than what was observed during the execution of elliptic drawings, a situation known to be highly favourable to the observation of the isochrony principle. For example, in the study by Viviani and Schneider (1991), an average increase of 50 cm in the perimeter of the drawing resulted in an average increase of 0.7 s in the movement duration in an adult group. In our experiment, a larger increase in trajectory length (from 8.82 cm to 70.56 cm) led to a relatively small increase in movement duration (0.14 s). However, the strength of the perceptual form of the isochrony principle could be explained by assuming that the constraints acting on perceptual judgment are weaker than those regulating execution. For example, force limitations that restrict the influence of the isochrony principle in real handwriting (Thomassen and Teulings 1985) could be ignored in the visual situation.

The results in the pointing condition were also different from what should be expected from Fitts’ law. Although the law predicts a logarithmic relation between pointing distance and movement time, a linear regression provided the best least-squares estimate in our perceptual task. The assumption that perceptual preferences are less constrained than actual production is appropriate to explain this linear tendency. The argument is as follows: Fitts’ law can be expressed in the form of a power function, 

\[ T_M = a + b(D/W)^n \] 

(Meyer et al 1990). This equation resembles the original formulation by Fitts (1954), but the authors added an exponent \( n \) that depended on the number of sub-movements necessary to reach the target. This equation accounts for the fact that for some combinations of distance and width pointing movements have a unique ballistic component (\( n \) equal to 1), and movement durations increase linearly with the index of difficulty. In fact, the logarithmic relation hinted by Fitts depends on the occurrence of sub-movements. In actual pointing, the spatial accuracy constraint often imposes final adjustments (ie sub-movements), whereas this constraint could be ignored in the perceptual situation because accuracy is already a property of the stimulus (ie the spot never misses the target). Moreover, the velocity profile of the pointing movement was bell-shaped. These characteristics of the pointing stimulus could have biased the participants’ perceptual preferences toward linearity.

However, the possible biases mentioned above cannot account for the difference measured between writing and pointing conditions. Even though the participants think that the production of human movements is organised by a unique principle of space–time co-variation (Decety and Michel 1989), their perceptual preferences concerning writing and pointing movement speed differ. The perceptual judgments concerning the speed of motion of single dots, portraying human movements, were influenced by principles that resemble those constraining the execution of the corresponding action.
This finding suggests that visual judgment and movement production share common representational resources in the spatiotemporal domain.

Acknowledgments. We thank Christel Ildei for helping in the experimental sessions, Frédéric Boy for his valuable advice on the manuscript, and Tahar Lallouache for skilfully developing the software. We greatly appreciate the anonymous reviewers for their very helpful contributions.

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